Quantitative Phase Contrast Imaging with a Segmented Detector in a Scanning X-ray Microscope or Microprobe

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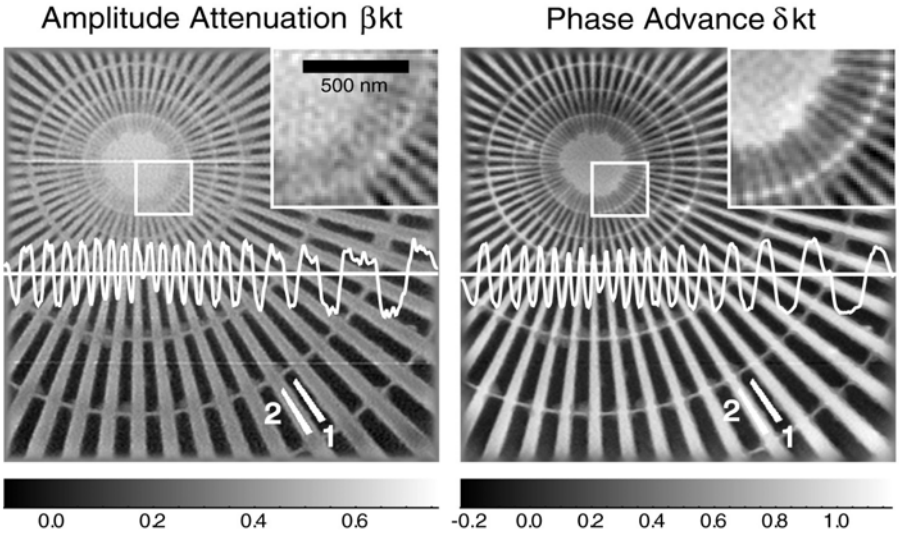
Scanning x-ray microscopes and microprobes are unique tools for the nanoscale investigation of specimens from the life, environmental, materials and other fields of sciences. In the soft x-ray range (below 1 keV photon energy), thus far they concentrate on studying chemical speciation of light elements by x-ray absorption near-edge structure (XANES) measurements. In the hard x-ray range (multi-keV), the main focus lies on trace element mapping by x-ray fluorescence.

Phase contrast provides a complementary contrast mechanism to absorption and fluorescence. In the soft x-ray range, it can help reduce the radiation dose imposed on the specimen by imaging at energies where absorption is low, but appreciable phase resonances occur. For harder x-rays, phase contrast allows the imaging of light elements with weak absorption and low fluorescence yield. Therefore it provides a means to map the ultrastructure of biological specimens and put trace elements (imaged by fluorescence) into their cellular context. In particular, there is strong demand for *quantitative* phase measurements of ultrastructure to obtain specimen thickness and therefore trace element concentrations rather than absolute amounts.

A segmented detector can be used to image the phase of the specimen in a scanning microscope or microprobe. This is done by measuring the redistribution of intensity in the detector plane caused by phase gradients in the specimen. We describe the application of such a segmented detector in the soft and hard x-ray range. Differential phase contrast, obtained from simple difference images of opposing detector segments, is easy to obtain and useful for a qualitative overview of specimen structure. Furthermore, we describe the application of a Fourier filtering algorithm to obtain quantitative maps of specimen amplitude and phase from segmented detector data, from which the specimen thickness can be inferred.



Germanium test pattern imaged at 525 eV photon energy. The recovered amplitude and phase shift agree well with the values expected from the thickness of the specimen. The phase image shows considerably more detail of the fine features. *B. Hornberger, M. Feser, and C. Jacobsen, Ultramicroscopy (2007),*